Proposed Nomenclature for Surface Features on Pluto and Its Satellites and Names for Newly Discovered Satellites

Eric E. Mamajek^{1*}, Valerie A. Rapson², David A. Cameron¹, Manuel Olmedo^{1,3}, Shane Fogerty¹, Eric Franklin¹, Erini Lambrides⁴, Imran Hasan⁵, Richard E. Sarkis¹, Stephen Thorndike⁶, Jason Nordhaus^{2,7,8}

- ¹ Department of Physics & Astronomy, University of Rochester, Rochester, NY, 14627-0171, USA
- ² School of Physics & Astronomy, Rochester Institute of Technology, 54 Lomb Memorial Dr., Rochester, NY, 14623, USA
- ³ Instituto Nacional de Astrofísica, Optica y Electrónica, Luis Enrique Erro #1 C.P. 72840, Tonatzintla, Puebla, México
- ⁴ American Museum of Natural History, Central Park W & 79th St., New York, NY 10024
- Department of Astronomy, Yale University, P.O. Box 208101, New Haven, CT, 06520-8101, USA
- ⁶ Monroe 2-Orleans BOCES, 3599 Big Ridge Rd., Spencerport, NY, 14559, USA
- Center for Computational Relativity and Gravitation, Rochester Institute of Technology, Rochester, NY, 14623, USA
- 8 National Technical Institute for the Deaf, Rochester Institute of Technology, Rochester, NY, 14623, USA

30 March 2015

ABSTRACT

In anticipation of the July 2015 flyby of the Pluto system by NASA's New Horizons mission, we propose naming conventions and example names for surface features on Pluto and its satellites (Charon, Nix, Hydra, Kerberos, Styx) and names for newly discovered satellites.

Key words: Kuiper Belt objects: individual (Pluto, Charon, Nix, Hydra, Kerberos, Styx) – planets and satellites: surfaces – solar system: general – standards

1 MOTIVATION

Pluto was considered a major planet between its discovery in 1930 by Clyde Tombaugh (Shapley 1930; Tombaugh 1946) and its reclassification by the International Astronomical Union (IAU) as a dwarf planet in 2006 (van der Hucht 2008)¹. Pluto appears to be a remarkably interesting object which sports an atmosphere, albedo variations, and an extensive satellite system (e.g. Elliot et al. 1989; Buie et al. 1992; Stern 1992; Owen et al. 1993; Brown 2002; Pasachoff et al. 2005; Weaver et al. 2006; Ward & Canup 2006; Elliot et al. 2007; Person et al. 2008; Stern 2008; Lellouch et al. 2009; Buie et al. 2010; Merlin et al. 2010; Tegler et al. 2010). A regularly updated bibliography of studies related to Pluto and its satellites is maintained by Robert L. Marcialis².

The NASA New Horizons (NH) Pluto-Kuiper Belt (PKB) mission is scheduled to fly by the dwarf planet Pluto and its satellite system on 14 July 2015³. Primary mission objectives for NH include investigating the geology,

morphology, and surface composition of Pluto and Charon (Stern 2008). High resolution images of Pluto and its satellites will soon be forthcoming in mid-2015, so discussion of ideas regarding naming conventions for surface features on these bodies is timely. The New Horizons team, in coordination with the International Astronomical Union, has initiated a public campaign for input on naming of features on Pluto and Charon⁴. This white paper combines input and discussions from several astronomers and current and past students in the Rochester area (mostly currently or recently affiliated with University of Rochester [AST 111 & 142 classes] and Rochester Institute of Technology).

2 NOMENCLATURE

Historically, many solar system objects have been named for mythological deities, as well as people and places from myths and classic literature from various cultures⁵. The general rules and conventions of planetary nomenclature have been outlined by the IAU^6 . The IAU Working Groups for Planetary System Nomenclature (WGPSN) maintains

 $^{^\}star$ E-mail contact: emamajek@pas.rochester.edu

¹ http://www.iau.org/public_press/news/detail/iau0603/

 $^{^2}$ http://www.lpl.arizona.edu/ \sim umpire/science/plubib.html

³ http://pluto.jhuapl.edu/

 $^{^4}$ http://www.ourpluto.org/vote

⁵ http://planetarynames.wr.usgs.gov/

 $^{^{6}\ \}mathrm{http://planetarynames.wr.usgs.gov/Page/Rules}$

a compilation of categories of surface features on solar system bodies along with the naming convention for each category⁷. The Working Group maintains a list of reputable sources which contain the spellings and descriptions of people, places, and things, which have been used for naming planetary features⁸ (e.g. Guirand 1977).

Thus far, only two naming conventions have been used for the Pluto system. Surface features of Pluto are to be named for "Underworld deities" ⁹. The IAU WGPSN and SBN ¹⁰ have adopted the following for the naming of Pluto's satellites: "Satellites in the plutonian system are named for characters and creatures in the myths surrounding Pluto (Greek Hades) and the classical Greek and Roman Underworld." ¹¹.

The dwarf planet Pluto and its largest satellite Charon manifest significant albedo variations, likely reflecting different types of complex terrain. Neptune's largest satellite Triton, which may be the most Pluto-like body yet imaged by spacecraft, has its surface features categorized by 12 different classes: catenae, cavi, craters, dorsa, fossae, maculae, paterae, planitiae, plana, plumes, regiones, sulci. There is some spectroscopic evidence (based on the presence of crystalline water ice and ammonia hydrates) that Charon may be experiencing cryovolcanism (Cook et al. 2007). It seems likely that imagery of the surfaces of Pluto and Charon may warrant a number of toponymic classes similar to that of Triton. In what follows, we summarize some suggestions which expand upon the existing IAU naming themes for the Pluto system.

2.1 Pluto

Pluto was discovered in 1930 by Clyde Tombaugh (Shapley 1930; Tombaugh 1946, 1960, 1997). In Greek mythology, Pluto was ruler of the underworld Hades, and represented a deity of wealth and treasure (Guirand 1977).

• Albedo features, Planitiae, Plana, Terrae, Dorsa, Maculae, Mensae, Tesserae: Deceased people and places associated with the discovery and characterization of Pluto: Tombaugh (Clyde William, 1906-1997; Tombaugh 1946, 1960, 1997), Lowell (Percival Lawrence, 1855-1916; began effort which lead to discovery of Pluto), Burney (Venetia Katharine Douglas Burney, 1918-2009; suggested name for Pluto), Kuiper (Gerald Peter, 1905-1973; Kuiper 1950, 1957), Elliot (James Ludlow, 1943-2011; Elliot et al. 1989; Elliot & Young 1992; Elliot et al. 2003, 2007)¹², Rabe (Eugene Karl, 1911-1974; Rabe 1957a,b), Hunten (Donald M., 1925-2010; Hunten & Watson 1982)¹³, Simonelli (Damon Paul, 1959-2004; Simonelli & Reynolds 1989;

Buratti & Veverka 2005), Bower (Ernest Clare, 1890-1964; Bower & Whipple 1930; Bower 1931, 1934; Hockey et al. 2009), Whipple (Fred Lawrence, 1906-2004; Bower & Whipple 1930; Yeomans 2004), Hardie (Robert, 1923-1989; Walker & Hardie 1955; Hardie 1965; Tenn 2007), Flagstaff, Coconino, Arizona (locations of Lowell observatory and USNO Flagstaff station where Pluto and Charon were discovered, respectively).

- Craters: Underworld deities and locations from mythologies around the world, excluding psychopomps (reserved for Charon; see §2.2). Examples: Mictlan (the Aztec underworld), Wepwawet (ancient Egyptian mythology; Hart 1990), etc.
- Catenae, Cavi, Chasmata, Fossae, Labryinthi, Montes, Paterae, Rupes, Scopuli, Sulci, Valles, Tholi: Words for "cold" in extinct or endangered languages 14 15. This is analagous to use of terms for "hot" for montes on Mercury 16. Words from documented extinct or endangered languages provide a nearly limitless (and thus far surprisingly underutilized) reservoir of names that may be used for celestial nomenclature. Examples: Nirum (Yaygir language, Australia; Crowley 1979), Hanglu (Siraya language, Taiwan; Adelaar 2011), Julu (Present-day Great Andamanese, Andaman Islands; Abbi 2013), etc.

Other potential themes for Pluto features: Geological features and archaeological sites of northern Arizona (region where both Pluto and Charon were discovered), names of famous coins or mints (given Pluto's association with wealth).

2.2 Charon (134340 Pluto I)

Charon was discovered by Christy & Harrington (1978) and "named after the Greek mythological boatman who ferried souls across the river Styx to Pluto for judgement". ¹⁷.

• Albedo features, Planitiae, Plana, Terrae: People associated with the discovery and characterization of Pluto's satellites, and mythological psychopomps (deities responsible for guiding spirits to the afterlife). Charon was discovered so recently (1978), that most notable scientists associated with its study are still alive, with a notable exception being Harrington (Robert Sutton, 1942-1993; Christy & Harrington 1978) who co-discovered Charon with Christy and was the first to calculate a dynamical mass for the Pluto-Charon system¹⁸. Mythological counterparts to Charon abound in the literature, with examples: Anubis (ancient Egyptian; Hart 1990), Muut (Cahuilla people of southern California; Bean 1974), Namtar (Mesopotamian; Black et al. 2004), Ixtab (Mayan), etc.

⁷ http://planetarynames.wr.usgs.gov/Page/Categories

 $^{^8}$ http://planetarynames.wr.usgs.gov/References

⁹ http://planetarynames.wr.usgs.gov/Page/Categories

¹⁰ http://www.ss.astro.umd.edu/IAU/csbn/

¹¹ http://planetarynames.wr.usgs.gov/Page/Planets

¹² http://web.mit.edu/newsoffice/2011/obit-elliot.html

 $^{^{13}\ \}mathrm{http://aas.org/obituaries/donald-m-hunten-} 1925-2010$

 $^{^{14}\ \}mathrm{http://www.unesco.org/culture/languages-atlas/index.php}$

¹⁵ http://www.endangeredlanguages.com/

¹⁶ http://planetarynames.wr.usgs.gov/Page/Categories

¹⁷ http://planetarynames.wr.usgs.gov/Page/Planets

 $^{^{18}\ \}mathrm{http://ad.usno.navy.mil/wds/history/harrington.html}$

• Craters: Names of characters, places, and starships associated with the Star Trek series of television shows and movies by American screenwriter and producer Gene Roddenberry (1921-1991). Examples: Kirk, Spock, McCoy, Sulu, Uhura, Chekov, Scotty, etc. (Okuda et al. 1999).

Gene Roddenberry worked on Star Trek between the mid-1960s and approximately 1990, which bracketed the discovery epoch of Charon (1978), the epoch of the Pluto-Charon mutual events (eclipses) which constrained the sizes of Pluto and Charon (1985-1990). It should be noted that there was popular support for naming one of the newly discovered satellites P4 or P5 "Vulcan". While "Vulcan" is obviously linked to a deity in classical mythology, its popularity was largely based on its use as the name of a fictional planet in Star Trek¹⁹. There is precedent of naming surface features on planetary satellites from science fiction and fantasy works from the 20th century. On Titan, the IAU has adopted the names of characters of Middle Earth from the novels of J.R.R. Tolkien for *colles* features, mountains and peaks from Middle Earth for *montes* peaks, and the names of planets from the Dune novels by Frank Herbert (e.g. Herbert 1965) for planitiae and labyrinthi. There are also asteroids named for fictional characters or shows from recent decades: e.g. (9007) James Bond and (13681) Monty Python being recent examples.

• Dorsa, Maculae, Mensae, Montes, Paterae, Tesserae, Tholi: Notable science fiction authors²⁰ who have written stories where Pluto and/or its satellites are featured. Examples: Coblentz (Stanton Arthur, 1896-1982; Coblentz 1931, 1934), Gallun (Raymond Zinke, 1911-1994; Gallun 1935), Heinlein (Robert Anson, 1907-1988; Heinlein 1958), Lovecraft (Howard Phillips, 1890-1937; Lovecraft 1930), Simak (Clifford Donald, 1904-1988; Simak 1973), Starzl (Roman Frederick, 1899-1976; Starzl 1931a,b), Walters (Hugh, 1910-1993; Walters 1973), Weinbaum (Stanley Grauman; 1902-1935; Weinbaum 1935), Williamson (Jack, 1908-2006; Williamson 1933, 1950). Kornbluth (Cyril M., 1923-1958) and Pohl (Frederik George, Jr., 1919-2013) coauthored three science fiction stories with Pluto as a setting under the pseudonyms S.D. Gottesman and Dennis Lavond (Gottesman 1940, 1941; Lavond 1941).

The list of science fiction authors is clearly heavy in American and western authors, so a broader survey of the international science fiction literature for notable deceased authors is obviously warranted if this nomenclature theme is adopted. Deceased Slavic authors who have written stories including Pluto as a setting are also not difficult to find: Shalimov (Alexander), Lukodjanov, Bulychov (Kir, alias of Igor Vsevolodovich Mozheiko), Bilénkin (Dmitri Aleksándrovitch; 1933-1987), Yemfrimov (Ivan Antonovich,

 $1908-1972)^{21}$. Unfortunately, at present we have only found incomplete translated bibliographic information on their works and birth/death dates.

• Catenae, Cavi, Chasmata, Fossae, Labyrinthi, Rupes, Scopuli, Sulci, Valles: Small towns, settlements, or islands serviced predominantly by ferry. Examples: Nias (Indonesia), Fogo (Canada), Robben (South Africa), etc.

2.3 Nix (134340 Pluto II = S/2005 P 2)

Nix was discovered in 2005 by Weaver et al. (2005), and the IAU WGPSN approved its designation in 2006. The adopted IAU spelling of the name is the Egyptian spelling of the Greek Nyx^{22} . In Hesiod's *Theogeny* (Hesiod 1914), Nyx was one of the first offspring of Chaos, "goddess of darkness and night, mother of Charon."

• Surface Features: Offspring of the Greek god Nyx. Nyx and her family are detailed in Hesiod (1914)²³. Examples: Moros, Ker, Hypnos, Momos, Oizys, etc. (Hesiod 1914).

2.4 Hydra (134340 Pluto III = S/2005 P 1)

Hydra was discovered in 2005 by Weaver et al. (2005), and the IAU WGPSN approved its desigation in 2006. The Lernaen Hydra "born of Typhon and Echidna, was an enormous serpent with nine heads," slain by Hercules (Guirand 1977).

• Surface features: People and places associated with the Greek mythological water monster Hydra. Examples: Typhon, Echidna, Heracles or Hercules, Lerna, Iolaus, etc. (Guirand 1977).

Note that "Sea creatures from myth and literature" ²⁴ has already been adopted by the IAU as the naming theme for maria on Titan, and so should not be reused for Hydra.

2.5 Kerberos (134340 Pluto IV = S/2011 (134340) 1)

Kerberos was discovered by Showalter et al. (2011). While the name Cerberus was proposed, it was already in use for an asteroid, and the name of the Greek counterpart Kerberos was adopted by the IAU. Kerberos was "the hound of Hades" (Hesiod 1914), a "monstrous watch-dog with fifty heads and a voice of bronze", although he was usually depicted with only three heads (Guirand 1977).

• Surface Features: Canine deities and monsters from mythology around the world. Chimera (Greek), Garmr or Garm (Norse), Fenrir (Norse; Guirand 1977), Amarok

 $^{^{19}\,}$ http://www.space.com/21814-pluto-moons-named-kerberosstyx.html

²⁰ The names and birth/death dates listed for the authors are as listed in Wikipedia (http://en.wikipedia.org), hence further verification is clearly warranted. A website listing science fiction works that involve Pluto as a setting is compiled by Steven H. Silver: http://www.sfsite.com/ silverag/pluto.html.

 $^{^{21}\,}$ Many thanks to Valentin Ivanov (ESO) for pointing us to these science fiction authors.

²² http://planetarynames.wr.usgs.gov/Page/Planets

 $^{^{23}\,}$ Nyx's place in the family tree of Greek mythological deities is shown at http://www.theoi.com/TreeHesiod.html

²⁴ http://planetarynames.wr.usgs.gov/Page/Categories

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(Inuit), Asena (Turkic), Kishi (Angola), Cú-Síth (Scotland), Inugami (Japan).

Thus far, no naming theme for any solar system body focuses on canine deities or monsters.

2.6 Styx (134340 Pluto V = S/2012 (134340) 1)

Styx was discovered by Showalter et al. (2012). Styx is "the infernal river" that separates Earth (the land of the living) from the underworld (the land of the dead) in Greek mythology. Styx was personified as a nymph born of Tethys and Oceanus (Guirand 1977).

• Surface Features: Rivers of mythological underworlds. Examples from Greek mythology: Acheron, Cocytus, Lethe, Phlegethon (Guirand 1977).

If a wider variety of nomenclature is needed, the nymph Styx from Greek mythology also had offspring with Pallas: Bia, Kratos, Nike, and Zelos (Guirand 1977).

3 NEW SATELLITES

Pluto's known satellites have been named Charon, Nix, Hydra, Kerberos, and Styx after mythological characters associated with the underworld from Roman or Greek mythology. Current models for forming Pluto and Charon favor a giant impact origin for the satellite system, where the outer satellites formed from an ice-rich, post-collision debris disk (Canup 2005; Stern et al. 2006; Canup 2011; Kenyon & Bromley 2014; Bromley & Kenyon 2015). Recent models by Kenyon & Bromley (2014) have predicted that the Pluto system may contain additional small satellites (<few km) beyond the orbit of Hydra at orbital radii of \sim 70-200 R_{Pluto}, with small inclinations with respect to Pluto-Charon. This region may contain an extremely low optical depth debris ring as well (Kenyon & Bromley 2014). It is also possible that the small satellites Nix and Hydra could harbor tiny coorbital satellites (Pires Dos Santos et al. 2011).

Based on input from the public, Mark Showalter submitted the names Vulcan and Cerberus to the IAU WGPSN and SBN committees for the satellites dubbed P4 and P5 (now Kerberos and Styx). Vulcan was rejected on the grounds that the name had been widely used to refer to a hypothetical planet that may exist closer to the Sun than Mercury (ruled out), and we are now left with the term 'vulcanoids' attached to the hypothetical population of asteroids which may orbit the Sun closer than Mercury's orbit (not ruled out). Cerberus was rejected due to its previous use with the asteroid 1865 Cerberus, however a transliteration of the Greek spelling Kerberos was adopted²⁵.

Showalter received several other good candidate names, including Elysium, Tartarus, Tantalus, Sisyphus, Orthrus,

²⁵ http://www.iau.org/public_press/news/detail/iau1303/

Melinoe, Hecate, Thanatos. These are briefly discussed and described on Showalter's blog²⁶. A search of the IAU Minor Planet Center compilation of minor planet names²⁷ shows that as of 8 March 2015, there are asteroids named (1866) Sisyphus, (2102) Tantalus, and (100) Hekate (close enough to Hecate that 'Hecate' should probably not be considered). However, there are no asteroids named *Tartarus*, *Orthrus*, *Melinoe*, or *Thanatos*. Arguably, these are all excellent candidate satellite names.

Tartarus (Latin) or **Tartaros** (Greek) represents the lowest region of the underworld – the region below even Hades where the Titans were imprisoned (Autenrieth 1891; Guirand 1977).

Orthrus or Orthus was a dog with two heads and the tail of a serpent from Greek mythology, and sibling of Kerberos (Cerberus). Orthrus, along with his master Eurytion, guarded a herd of red oxen controlled by the monster Geryon. Orthrus (along with seemingly every other interesting beast in Greek mythology) was slain by Hercules. The name was spelled as *Orthus* in Hugh Evelyn-White's English translation of Hesiod's *Theogeny* (Hesiod 1914), and referred to as "Orthus, the hound of Geryones, born of Echidna and Typhaon, slain by Heracles". The same monster is spelled as Orthrus in Guirand (1977). There is, however, an asteroid (2329) Orthos, of similar spelling.

Melinoe was an underworld goddess in Greek mythology who made nightly earth visits, spreading fear with her ghastly companions. Her name translates roungly to "dark mind", and she is described in detail in Orphic Hymn LXX "To Melinoe, the Fumigation from Aromatics" (Taylor 1896; Athanassakis 2013). Representing her mixed heritage as the daughter of Zeus and Persephone, Melinoe's limbs were dark on one side, but white on the other (Taylor 1896). Melinoe may be a particularly appropriate name for a new satellites with high contrast surface features.

Thanatos (Greek) or Mors (Latin) was the god of non-violent death²⁸. He is often depicted with his twin brother, Hypnos, who was the god of sleep. Thanatos and Hypnos were sons of Nyx (goddess of night) and Erebos (god of darkness). Thanatos could rarely be defeated, tricked, or captured by Greek gods and heroes (Heracles, Sisyphus) who wished to prevent a death or escape their own death (Hesiod 1914). Thanatos was also the subject of an Orphyic hymn "To Thanatos, Fumigation from Manna" (Taylor 1896; Hansen 2004; Athanassakis 2013). With Thanatos being a son of Nyx, its name could be used for a surface feature on Nyx instead.

 $^{^{26}}$ http://cosmicdiary.org/mshowalter/2013/02/14/opening-up-the-gates-of-hell/

 $^{^{27}~{\}rm http://www.minorplanetcenter.net/iau/lists/MPNames.html}$

²⁸ http://www.theoi.com/Daimon/Thanatos.html

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